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Attention to the face is characterised by a difficult to inhibit first fixation to the eyes

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ABSTRACT

The eyes are preferentially attended over other facial features and recent evidence suggests this bias is difficult to suppress. To further examine the automatic and volitional nature of this bias for eye information, we used a novel prompting face recognition paradigm in 41 adults and measured the location of their first fixations, overall dwell time and behavioural responses. First, patterns of eye gaze were measured during a free-viewing forced choice face recognition paradigm. Second, the task was repeated but with prompts to look to either the eyes or the mouth. Participants showed significantly more first fixations to the eyes than mouth, both when prompted to look at the eyes and when prompted to look at the mouth. The pattern of looking to the eyes when prompted was indistinguishable from the unprompted condition in which participants were free to look where they chose. Notably, the dwell time data demonstrated that the eye bias did not persist over the entire presentation period. Our results suggest a difficult-to-inhibit bias to initially orient to the eyes, which is superseded by volitional, top-down control of eye gaze. Further, the amount of looking to the eyes is at a maximum level spontaneously and cannot be enhanced by explicit instructions.

1. Introduction

Surveying a crowded room, your eyes meet with a stranger and you quickly look away. Making eye contact was not the intention but it happened anyway. The reason for this exchange may lie in our strong and automatic preference for looking at the eyes of a face.

This bias is perhaps not surprising given evidence of preference for human eyes and eye contact in infants. Newborns show a preference for direct gaze over averted gaze (Farroni, Csibra, Simion, & Johnson, 2002) as well as open over closed eyes (Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000), while by three months infants show a preference for human eyes over nonhuman primate eyes (Dupierrix et al., 2014). This early development of eye processing preferences concurs with evidence that the neural response to the eyes matures in children before the neural response to a full face (Taylor, Edmonds, McCarthy, & Allison, 2001).

The finding that the eyes are preferentially attended over other facial features and body parts is robust and well-replicated across a variety of tasks (e.g. Birmingham, Bischof, & Kingstone, 2009; Foulsham & Sanderson, 2013; Guo, Smith, Powell, & Nicholls, 2012; Heisz & Shore, 2008; Henderson, Williams, & Falk, 2005; Janik, Wellens, Goldberg, & Dell'Osso, 1978; Laidlaw & Kingstone, 2017; Laidlaw, Risko, & Kingstone, 2012; Pelphrey et al., 2002; Scheller, Buchel, & Gamer, 2012; Schyns, Petro, & Smith, 2007). The primacy of the eyes is consistent with evidence of their relevance to the 'social brain' (e.g. Birmingham & Kingstone, 2009; Emery, 2000; Senju & Johnson, 2009). For example, eye gaze is relevant to understanding other people's mental states (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001), with direct gaze signalling intent to communicate and activating brain regions, including the medial prefrontal cortex and temporal parietal junction, commonly implicated in mental state understanding (e.g. Caruana, Brock, & Woolgar, 2015; Cavallo et al., 2015; Conty, N'Diaye, Tijus, & George, 2007; Ethofer, Gschwind, & Vuilleumier, 2011; Kampe, Frith, & Frith, 2003).

Related to their social significance, the eyes are argued to play a distinct role in face processing, with face detection being attenuated when the eyes are masked (Lewis & Edmonds, 2003). Further, face recognition is poorer when the eyes are not attended (Laidlaw & Kingstone, 2017) or given less attention (Hall, Hutton, & Morgan, 2010), and enhanced when the first fixation is to the eyes, rather than mouth (Hills, Cooper, & Pake, 2013). Indeed, looking just below the eyes has been identified as optimal for face recognition (Peterson &

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Eckstein, 2012), while the Bubbles technique indicated the eyes were the most diagnostic region of the face for gender and identity recognition (Gosselin & Schyns, 2001; Vinette, Gosselin, & Schyns, 2004). Previous research also shows that initial orientation to the face during both face recognition and free viewing is to the eye region (e.g. Brielmann, Bulthoff, & Armann, 2014; Peterson & Eckstein, 2012; van Belle, Ramon, Lefevre, & Rossion, 2010; van der Geest, Kemner, Verbaten, & van Engeland, 2002).

Although the bias to look at the eyes relative to other facial features is a well-established finding, there is limited understanding of the mechanisms that drive this effect. One obvious consideration is the extent to which eye looking is under top-down volitional control compared to the extent to which it is an automatic and reflexive process, triggered bottom-up by the stimulus (Laidlaw et al., 2012). The argument for automatic and reflexive responding is supported by existing findings. For example, Kliemann, Dziobek, Hatri, Steimke, and Heekeren (2010) used an emotional recognition task with a short viewing period (150 ms) to try to understand initial and reflexive viewing patterns to the face. Adults were significantly more likely to orient their gaze upward towards the eyes (when initially fixated on the mouth) than adjust their gaze downwards away from the eyes (when initially fixated on the eyes). In another study, Laidlaw et al. (2012) used a novel paradigm to directly test volitional and automatic aspects of eye bias. Participants were explicitly asked not to look at either the eyes or mouth. Those who were told not to look at the eyes made more errors (i.e. fixations to the eyes) than would be expected with a random fixation pattern. In contrast, participants demonstrated strong suppression of mouth looking when told to ignore the region. The data suggest volitional control of mouth looking in the absence of full volitional control of fixations to the eyes. This finding was replicated by Laidlaw and Kingstone (2017) who also showed that face discrimination suffered when fixations to the eyes were avoided during initial viewing, and that covert viewing of the eyes was not sufficient to confer an encoding advantage.

In the current study we examine the nature of these automatic and volitional components of eye looking further. It is notable that Laidlaw et al. (2012) found that participants who were told not to look at the eyes spent significantly longer looking to the eyes in the early viewing period (first 1000 ms) than the late viewing period (fixations starting after 1000 ms). This suggests that the unconscious bias to look at the eyes may be more difficult to inhibit during the relatively early period of face viewing and it could be inferred that faster automatic processes are superseded by slower volitional processes. Following previous work using first fixations to measure attentional priority (Fletcher-Watson, Findlay, Leekam, & Benson, 2008), our paradigm offers a more fine-grained analysis of this time course by measuring the location of the first fixation to the face. Laidlaw and colleagues' (Laidlaw et al., 2012; Laidlaw & Kingstone, 2017) methodology also required participants to avoid looking at features. Given the known challenges of thought suppression (Wenzlaff & Wegner, 2000), instructing participants within a negative frame i.e. not to look at the eyes, may be more challenging than positive instruction to look to the mouth. Further, Laidlaw and colleagues' instructions did not have any clear benefit for participants; indeed the original study did not require any judgement of the faces (Laidlaw et al., 2012). We designed a paradigm where participants were not only given a positive instruction on where to fixate, but it was made clear that following the instructions would optimise performance. Therefore our paradigm was designed as a stronger challenge for any automatic bias by framing instructions for volitional looking within a positive frame, and by providing a salient motivation for following the instructions.

In the task designed for the current study, participants first had to make a forced-choice face recognition in a condition where viewing was free. For the second condition, the forced-choice face recognition was supported by trial-by-trial prompts to look at either the eyes or mouth, accompanied by the instruction that following the prompt would benefit performance. We used the digitally-manipulated photographic face stimuli of Joseph and Tanaka (2003), which included target faces and matched comparison faces where facial features had been replaced with alternatives. These stimuli enabled us to create a face recognition paradigm where differences were specific to the eyes and mouth, enabling our prompt cues to have explicit validity as aides to performance. We were interested both in the location of the first look as well as the overall dwell time. These measures allowed us to consider whether a putative automatic first fixation to the eyes could be later modified by top-down attention control. The eye tracking data were complemented by behavioural measures (accuracy and reaction time) that investigated how effectively looking patterns were utilised. If there is a dominant orientation to the eyes that is difficult to inhibit we expected to see a higher number of first looks to the eyes, regardless of instructions. We expected this initial orientation to be superseded by slower volitional looking that follows task instruction, as measured by dwell time across the entire looking period.

2. Method

2.1. Participants

Forty-one participants (14 male, 27 female), aged between 20 and 37 (mean = 26.44 years, SD = 3.54) took part in this study. This sample size was suitably powered for detecting a medium effect size (which would require 34 participants in a within-subjects design at 80% power) and compares favourably with the previous studies in this area (e.g. Laidlaw et al., 2012). All participants reported either normal, or corrected to normal vision. Approval for this study was provided by the University of Essex ethics committee.

2.2. Apparatus

Participants sat in an adjustable height chair with their chin on an adjustable height chin rest that was placed centrally 57 cm in front of a screen. The stimuli were presented on a 19″ Dell 1908FP LCD PC screen, with a resolution of 1024 × 768 and a refresh rate of 60 Hz. An Eyelink 1000 system (SR Research, Mississauga, Canada) recorded eye movements, accuracy and reaction time for the 700 ms when the target image was on the screen, and a button box was used for participants to make their responses.

2.3. Materials

Stimuli were created by Joseph and Tanaka (2003) and were greyscale digital photographs of 12 children's faces with a neutral expression (see Fig. 1 for an example). At the fixed viewing distance, each face subtended approximately 14 × 21 degrees of visual angle and was presented against a dark grey background. The images were digitally altered and created from a large pool of original photographic images of children. Twelve target images were created using the features (eyes, nose, mouth) and face outline from different children. Each target was paired with three foil images, where either the eyes, nose or mouth was replaced with one from an unused photograph. The nose foils were included as a filler to create a more demanding task (i.e. three potential sources of change, rather than two) and were not analysed. In total, there were 36 pairs of images (12 targets × 3 foil types).

The pairs of images were separated into two groups of 18 (6 targets × 3 foil types). The group of images that was assigned to the unprompted or prompted condition was counterbalanced across participants. Further, each set of 18 images was repeated twice within the condition to enable more data collection, and the order of trials was randomised. In summary, each participant completed 72 trials, 36 in the unprompted condition (18 images × 2 repetitions) and 36 in the prompted condition (18 images × 2 repetitions). Forty eight of the trials (eye and mouth trials) were included in the analysis.

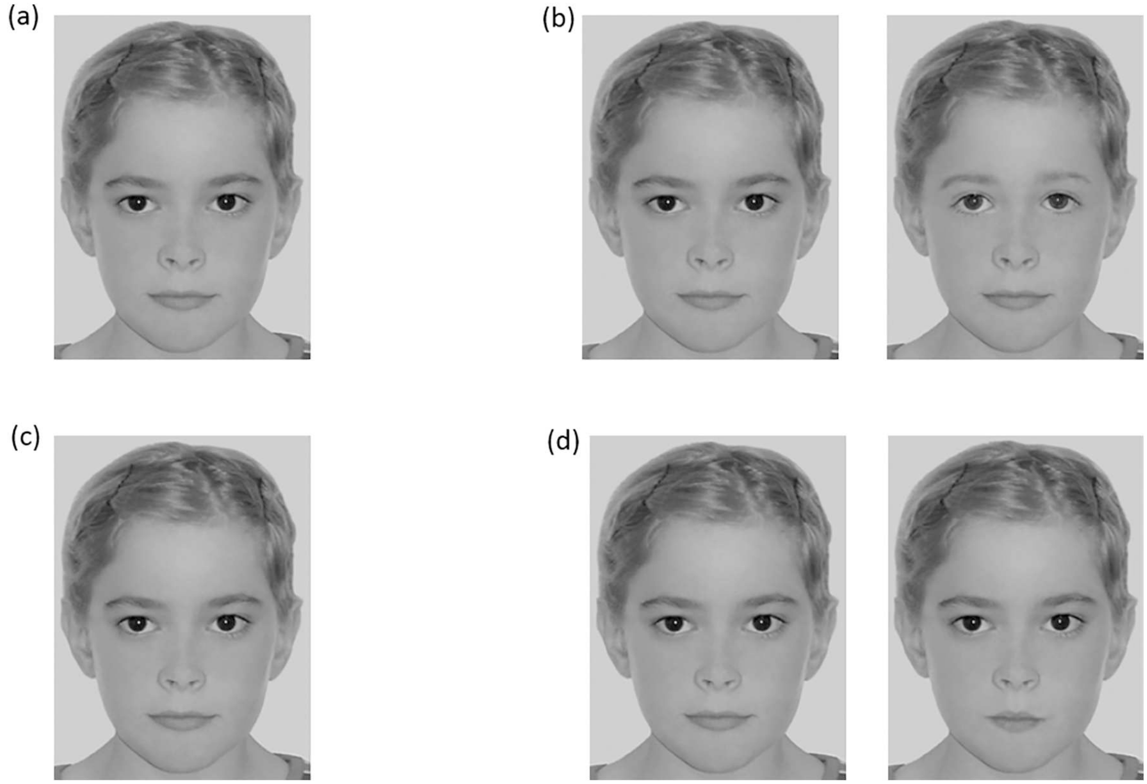

Fig. 1. (a,b) Example of trial with an eye change. Target stimulus (a) followed by a forced choice (b) between the target stimulus and a foil stimulus with different eyes. (c,d) Example of trial with a mouth change. Target stimulus (c) followed by a forced choice (d) between the target stimulus and a foil stimulus with a different mouth.

2.4. Design

Participants completed a forced-choice face recognition paradigm, in which a target was presented followed by the target and a foil. Two variables were manipulated. Firstly, a region of the face was changed on the foil image, either the eyes, nose or mouth ('changed region'). Secondly, the first half of the trials were completed without a prompt and the second half of the trials involved a prompt to this changed region ('unprompted' and 'prompted'). This order was fixed, as having the prompted condition first would influence the free viewing in the unprompted condition. Behavioural data collected were accuracy (percentage of correct responses) and reaction time (average time of response, in ms). Measures of eye gaze were taken during the initial presentation of the target image and were for total dwell time (the total time dwelling in each region of interest (ROI), in ms) and the location of the first look to the target image after the first saccade away from the fixation point (percentage of first fixations to each ROI).

2.5. Procedure

Participants were tested individually in an eye tracking laboratory. Before each set of trials a nine-point calibration and validation procedure was completed. The calibration was considered valid if the average error was < 0.8 degrees of visual angle. The maximum allowed error on any single point was 2.0 degrees of visual angle. If validation errors were too high the calibration procedure was repeated until the desired set-up was established.

Each trial began with the presentation of a fixation point, consisting of a dot appearing randomly in one of the four corners of the screen, 50 pixels from each edge. Participants were required to look at the point and press a button on their button box. The button press initiated the presentation of the target stimuli but only if the point was being successfully fixated. This manipulation ensured that the eye tracking data were not biased by systematic differences in starting eye positions. The target stimulus was presented on the screen for 700 ms. Immediately afterwards the two choice images were presented on the screen side by side. Participants were informed that their task was to select the face they thought was identical to the initial face image. Responses were recorded using the button box.

For the prompted condition, an additional instruction was included. Prior to each trial and before the fixation point, a word appeared in the centre of the screen saying either "eyes", "nose" or "mouth". Participants were informed that following this instruction would help them decide the target image. It was made clear to participants that this prompt would always be accurate, they would not be deceived and it would always be helpful to look at the area of the face indicated.

These data were collected as part of a wider study, which included the collection of questionnaire measures. These measures were not directly relevant to the current questions of interest and are not reported.

2.6. Eye tracking ROIs

ROIs were defined to enable analysis of fixations occurring in important regions of the target face. The eye and mouth ROIs were different sizes, reflecting the different amount of space occupied by each region. The eye ROI consisted of a rectangle incorporating the eyes, eyebrows and the region between the eyes, and the mouth ROI consisted of a rectangle around the mouth. ROIs were drawn individually for each target image to best fit individual differences in morphology (for an example see Fig. 2), but there were only minor differences between faces. The eyes ROI had mean dimensions of 9.1 × 3.0 degrees (246 × 81 pixels). The mouth ROI was smaller, with mean dimensions of 5.0 × 2.3 degrees (134 × 62 pixels). Some previous studies have used an area normalisation process to account for the possibility of a larger ROI acquiring more fixations by chance if a participant looks randomly across the screen (e.g. Bindemann, Scheepers, & Burton,

Fig. 2. Example of the regions of interest (ROI) for a target stimulus. The stimulus is shown as presented during the experiment, centred on a dark grey background.

2009; Birmingham, Bischof, & Kingstone, 2008; Fletcher-Watson et al., 2008; Laidlaw et al., 2012). However, this approach relies on assumptions about larger ROIs receiving more fixations, which may not be correct (Hessels, Kemner, van den Boomen, & Hooge, 2016). We report raw data throughout the main body of the report, but area normalised data (taking into account the different sizes of the ROI) is presented in Appendix A. In cases where area normalisation leads to a different pattern of results, we comment on these in the results. Importantly, the size of an ROI, and therefore the choice to normalise by area, can only affect comparisons between *different* ROIs (e.g., the eyes being fixated "more" than the mouth) and not comparisons between the *same* ROIs in different tasks (e.g., the eyes being fixated more or less with particular instructions).

3. Results

3.1. Data cleaning

The data were cleaned of invalid trials, based on atypical eye tracking responses. First, trials were removed where the participant was not looking at the fixation point at the point of trial onset. Second, trials were removed where no fixations were made to the target image during initial presentation. In total 65 trials were removed (21 unprompted and 44 prompted), leaving 1903 trials for analysis (96.7% of the original trials). This represents an average of 1.59 (SD = 1.94) of 48 trials removed per participant.

3.2. Behavioural data

Data were not normally distributed so were log transformed; all statistical tests use the log transformed data. Accuracy data were analysed to allow a comparison of the success of the participant when the eyes and mouth were the changed region and how this differed in the unprompted and prompted conditions (see Fig. 3). A repeated measures 2 (prompt: unprompted or prompted) x 2 (changed region: eye or mouth) ANOVA found people were significantly more accurate when prompted than when not prompted, $F(1,40) = 42.22$, $p < 0.001$, $\eta_p^2 = 0.51$, 90% CI [0.32, 0.63] and accuracy was significantly higher when the eyes were the changed region than when the mouth was the changed region, $F(1,40) = 13.63$, $p = 0.001$, $\eta_p^2 = 0.25$, 90% CI [0.08, 0.41]. In addition there was a significant interaction, $F(1,40) = 4.15$, $p = 0.048$, $\eta_p^2 = 0.09$, CI 90% [0.00, 0.25]. This interaction was explored with post hoc paired sample *t*-tests (using Bonferroni corrected threshold of $p < 0.025$), showing participants were significantly more accurate when the eyes (vs. mouth) were the changed region in the unprompted condition, $t(40) = 3.16$, $p = 0.003$, $d_{av} = 0.67$, 90% CI [0.31, 1.03]. In the prompted condition accuracy was also greater when the eyes (vs. mouth) changed, however, this difference was smaller and did not reach corrected significance, $t(40) = 2.32$, $p = 0.025$, $d_{av} = 0.48$, 90% CI [0.13, 0.83].

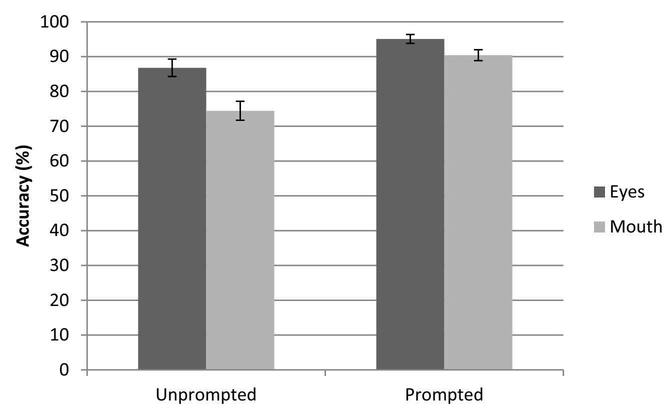

Fig. 3. Accuracy in the unprompted and prompted conditions, compared for when the eyes and mouth were the changed region (error bars show standard error).

Reaction time data were also analysed as shown in Fig. 4. A repeated measures 2 (prompt: unprompted or prompted) x 2 (changed region: eye or mouth) ANOVA was performed and found participants performed significantly faster in the prompted condition, $F(1,40) = 32.58$, $p < 0.001$, $\eta_p^2 = 0.50$, 90% CI [0.25, 0.58]. There was no significant different in reaction time depending on whether the eyes or mouth were the changed region, $F(1,40) = 0.86$, $p = 0.36$, $\eta_p^2 = 0.02$, 90% CI [0.00, 0.14], but there was a significant interaction, $F(1,40) = 13.68$, $p = 0.001$, $\eta_p^2 = 0.26$, 90% CI [0.08, 0.41]. Explorations with post-hoc paired sample *t*-tests (Bonferroni threshold of $p < 0.025$) revealed that participants were significantly quicker at

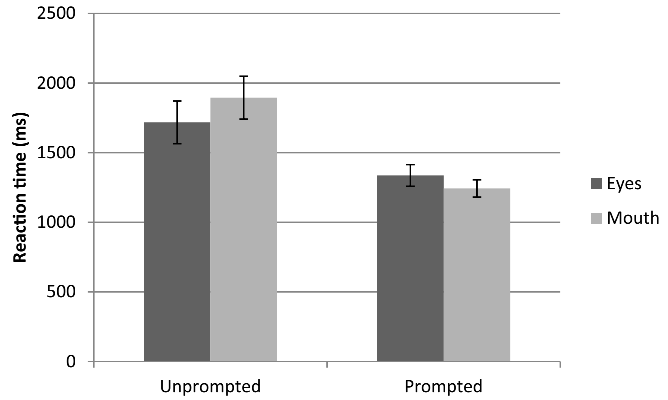

Fig. 4. Mean reaction time in the unprompted and prompted conditions, when the eyes and mouth were the changed region (error bars show standard error).

identifying changes to the eye region than the mouth region when no prompt was provided, $t(40) = -3.99$, $p < 0.001$, $d_{av} = 0.25$, 90% CI [0.15, 0.35], but when the prompt was provided there was no longer a significant difference, $t(40) = 1.33$, $p = 0.19$, $d_{av} = 0.13$, 90% CI [0.05, 0.44].

3.3. Eye tracking data

3.3.1. Unprompted looking patterns

The eye tracking data were significantly skewed and this could not be corrected by transforming the data. Non-parametric and parametric tests produced the same pattern of results, so for ease of communication the parametric tests have been reported. The unprompted eye tracking data were used to analyse participants' spontaneous looking patterns when viewing the target face image. A *t*-test showed that participants' first fixations were significantly more often to the eyes (mean = 36.61%, sd = 16.20) than the mouth, which was very rarely fixated first (mean = 0.93%, sd = 2.28), $t(40) = 13.31$, $p < 0.001$, $d_{av} = 3.86$, 90% CI [3.37, 4.35]. Total dwell time indicated that participants spent a considerable portion of the 700 ms trial time looking at the eyes (mean = 259.10 ms, sd = 84.75). In contrast, because the mouth was often not fixated at all during the trial it was associated with a very low total dwell time, which was significantly different from the amount of looking to the eyes (mean = 6.67 ms, sd = 11.77), $t(40) = 17.77$, $p < 0.001$, $d_{av} = 5.23$, 90% CI [4.73, 5.73].

3.3.2. Effects of prompting on looking patterns

The effect of prompting on people's natural looking patterns is shown in Figs. 5 and 6. A 2 (prompt location: eye or mouth) x 2 (ROI: eyes and mouth) repeated measures ANOVA was conducted with the

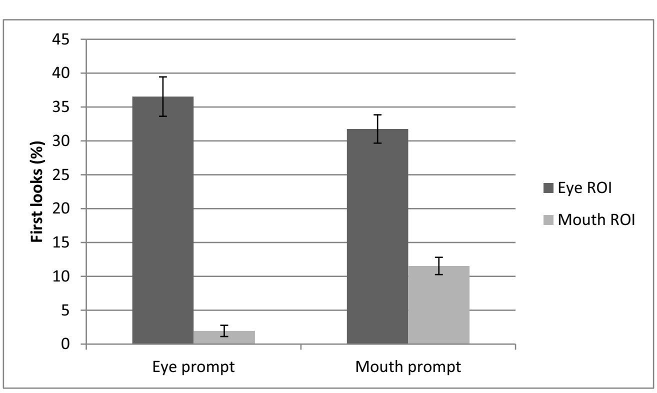

Fig. 5. First looks to the eye and mouth regions of interest (ROI) when prompted to look to the eyes or mouth (error bars show standard error).

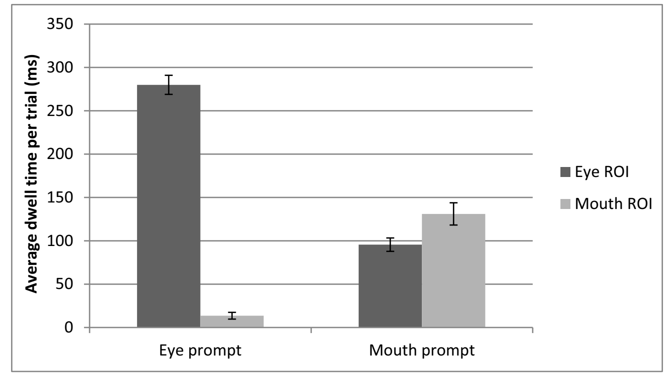

Fig. 6. Mean dwell time for the eye and mouth regions of interest (ROI) when prompted to look to the eyes or mouth (error bars show standard error).

first look data. We found no significant main effect of prompt location, $F(1,40) = 2.57$, $p = 0.12$, $\eta_p^2 = 0.06$, 90% CI [0.00, 0.20], but a significant effect of ROI, $F(1,40) = 117.47$, $p < 0.001$, $\eta_p^2 = 0.75$, 90% CI [0.62, 0.81], and a significant interaction, $F(1,40) = 12.25$, $p = 0.001$, $\eta_p^2 = 0.23$, 90% CI [0.07, 0.40]. Post hoc *t*-tests (Bonferroni threshold of $p < 0.025$) revealed that when participants were prompted to look to the eyes their first fixation on the target image was significantly more often to the eyes (mean = 36.54%, sd = 18.60) than the mouth (mean = 1.95%, sd = 5.30), $t(40) = 10.53$, $p < 0.001$, $d_{av} = 2.89$, 90% CI [2.43, 3.36]. When prompted to look to the mouth, participants' first fixation was also more often to the eyes (mean = 31.76%, sd = 13.40) than the mouth (mean = 11.54%, sd = 11.06), $t(40) = 6.26$, $p < 0.001$, $d_{av} = 1.65$, 90% CI [1.21, 2.10]. In fact, while there were slightly fewer first fixations on the eyes in the mouth prompt condition, there was no significant difference in first looks to the eyes between the eye and mouth prompt conditions, $t(40) = 1.50$, $p = 0.14$, $d_{av} = 0.30$, 90% CI [−0.04, 0.63]. However, participants looked significantly more often to the mouth when prompted to do so, $t(40) = 5.72$, $p < 0.001$, $d_{av} = 1.17$, 90% CI [0.83, 1.52].

When the first fixation data were normalised by area (see Appendix A) the results were similar, although in this case there was no significant difference in the number of first looks to the eyes and mouth in the mouth prompt condition. In summary, both sets of data suggest a inhibiting first looks to the eyes when told to look at the mouth.

We next examined total dwell time during the prompted trials using a 2 (prompt location: eye or mouth) × 2 (ROI: eyes and mouth) repeated measures ANOVA. We found a significant main effect of prompt location, $F(1,40) = 35.58$, $p < 0.001$, $\eta_p^2 = 0.47$, 90% CI [0.27, 0.60], a significant effect of ROI, $F(1,40) = 118.58$, $p < 0.001$, $\eta_p^2 = 0.75$, 90% CI [0.62, 0.81], and a significant interaction, $F(1,40) = 162.33$, $p < 0.001$, $\eta_p^2 = 0.80$, 90% CI [0.70, 0.85]. This interaction is the result of participants looking significantly more at the eyes (279.93 ms, sd = 70.47) than the mouth (13.57 ms, sd = 24.90) when prompted to look at the eyes, $t(40) = 149.83$, $p < 0.001$, $d_{av} = 5.59$, 90% CI [5.11, 6.06], but showing no significant difference in looking to the mouth (131.04 ms, sd = 82.16) and the eyes (95.57 ms, sd = 49.50) when prompted to look to the mouth, $t(40) = 1.97$, $p = 0.06$, $d_{av} = 0.54$, 90% CI [1.45, 2.12]. The eyes were looked at longer in the eye prompt condition than in the mouth prompt condition, $t(40) = 13.91$, $p < 0.001$, $d_{av} = 3.07$, 90% CI [2.70, 3.45], whereas the mouth ROI was looked at longer in the mouth prompt condition $t(40) = 9.07$, $p < 0.001$, $d_{av} = 2.19$, 90% CI [1.79, 2.60].

When the data were normalised according to ROI area (see Appendix A), the only change in the results was that the difference between ROIs in the mouth prompt condition was now statistically significant, i.e. participants looked significantly more to the mouth than the eyes. In both data sets, there is an effect of task instructions.

Therefore, despite the fact that, even when prompted, the mouth was not preferred on the first fixation, participants were subsequently able to adjust their looking patterns in line with the prompt (e.g. by terminating a fixation on the eyes and looking to the prompted mouth).

3.3.3. Comparison of eye looking in unprompted and eye prompted conditions

We observed that the pattern of looking to the eyes was similar in the unprompted condition and in the prompt to the eyes condition. Therefore, we were interested in whether prompting to the eyes significantly enhances looking in this region, or whether eye looking is already at a maximum level in a spontaneous, unprompted condition. Using *t*-tests, we found there were no differences between these two conditions, for both first fixations and dwell time (all $ps < 0.05$), suggesting eye looking is already at maximum capacity in the unprompted condition.

4. Discussion

We developed a novel prompting paradigm, based around a forced choice face recognition task, to explore how attention is oriented to the eyes and mouth. By examining the location of first fixations, we found a strong bias to orient to the eyes. This bias was reflected in reduced ability to follow instructions to look to the mouth compared to the eyes, even though participants were aware that the instructions facilitated task performance. This pattern is compatible with the eyes automatically drawing attention. In addition, we found no significant difference in looking patterns between a prompted condition, in which participants were explicitly instructed to look to the eyes, and an unprompted condition in which they had no instructions but spontaneously tended to look to the eyes first and for longer. Taken together, these findings add to a body of literature that indicate the eyes have a special attentional salience and highlight the dominance of the bias to look to eyes. Not only do the findings show a bias that is difficult to overcome, but this bias is at a maximum level naturally and cannot be enhanced by the type of explicit instruction used in the current study.

Previous research by Laidlaw et al. (2012) and Laidlaw and Kingstone (2017) found that participants had difficulty inhibiting looking to the eyes when told not to look at the region. Our results support this finding in a task that could be considered a stronger challenge for any eye bias as instructions asked participants to orient towards a region, rather than avoid a region. This meant there was no mention of 'eyes' when participants had to look to the mouth and therefore eyes held no cognitive saliency (see Wenzlaff & Wegner, 2000). Further, following the instructions was of explicit benefit to participants, providing strong motivation to orient to the mouth when prompted. Even with these manipulations, our data were clear in replicating Laidlaw et al.'s findings of a difficult to inhibit bias to look towards the eyes.

Our findings go beyond those of Laidlaw and colleagues (Laidlaw et al., 2012; Laidlaw & Kingstone, 2017) in considering both the first fixation and the overall dwell time for the 700 ms stimulus presentation. In the current study, there was a clear preference for first fixating on the eyes in the eye prompt condition and also in the mouth prompt condition. Even when correcting for the fact that the eyes were larger, the pattern of normalised data still did not show a preference for the mouth when prompted. Indeed, the amount of first looks to the eyes was not significantly different between the two prompting conditions. However, there was evidence of following task instructions when considering total dwell time. Here we found that the overall time spent looking at the eyes was greater when instructed to look at the eyes and the overall time spent looking at the mouth was greater when instructed to look at the mouth. Considering each prompting condition separately, the eyes were looked at more than the mouth in the eye prompt condition and but there was no significant difference in eye and mouth looking for the mouth prompt condition. However, when adjusting for the larger eye ROI, the mouth prompt condition did produce significantly more looks towards the mouth than the eyes. Laidlaw et al. (2012) found difficulty in supressing looks to the eyes across the 5000 ms of their stimulus presentation, although with stronger effects during the first 1000 ms. In comparison, the bias to the eyes in our experiment appears to be more fleeting, which may relate to the differences in task instructions. However, the common pattern across both studies is that initial orienting to the eyes is difficult to inhibit, while looking over a longer period is more amenable to top-down control.

The extent to which this initial orientation can be considered an automatic, bottom-up process is an important question. Certainly, the initial eye bias meets a key criterion, the intentionality criterion, for automaticity in that it was not significantly disrupted by intention to orient to the mouth (Yantis & Jonides, 1990). The second key criterion, which was not tested, is the load-insensitivity criterion (Yantis & Jonides, 1990). This would predict the eye bias would be robust to increases in cognitive or perceptual load, such as a more complex visual stimulus. However, although the eyes were the facial feature that was oriented to most strongly, they only accounted for about 37% of first looks when unprompted. Therefore, looking to the eyes first is not inevitable, which would be the prediction of a strong form of the automatic hypothesis. It is worth noting two other studies investigating first looks to the eyes report higher percentages of first looks of approximately 45–55% (Brielmann et al., 2014; van der Geest et al., 2002), and methodological and measurement factors may account for this variance.

An important secondary finding of the research is that looking to the eyes is already at a maximum level when viewing a face using self-directed looking. Specifically, there was no significant difference in the number of first fixations and dwell time between the unprompted condition and the eye prompt condition, where participants were explicitly told to look at the eyes. As far as we are aware, this is the first study to show that looking to the eyes is naturally at a person's maximum threshold. This optimal behaviour may occur spontaneously because of the pivotal role of eye gaze in social communication (e.g. Emery, 2000; Hamilton, 2016).

The behavioural accuracy and RT data gave insight into the impact of looking patterns on performance. Behavioural data for the unprompted condition reflected the eye tracking results in indicating a natural advantage for detecting changes to the eye region compared to the mouth region, which replicates the pattern of findings reported by Joseph and Tanaka (2003), who used the same stimuli but with children. However, the significant interactions for both the RT and accuracy data indicated that the relative advantage for detecting changes to the eye region was reduced when the prompt was provided. Indeed, this pattern was totally eliminated for RT. This could be explained by the participants' ability to increase their overall time looking to the mouth when prompted to do so, even if their initial bias to look to the eyes did not support behavioural performance. This pattern of behavioural data highlights the relevance of attentional biases to the ability to recognise and discriminate faces.

A key question is why there is such a strong drive to orient to the eyes. The answer perhaps lies in the complementary motivations to both share our social intent with others, as well as to effectively read another person's intentions. This reciprocal exchange lies at the heart of social communication and is heavily influenced by eye gaze. Eye contact with another has been associated with positive evaluations including enhanced attractiveness and pleasantness, as well as communicating personal attributes and social signals such as competence, attentiveness, assertiveness, credibility, intensity of feelings and dominance (see Frischen, Bayliss, & Tipper, 2007; Kleinke, 1986). Rapid orientation to the eyes may be an important mechanism that ensures that essential social information is both communicated and ascertained. For example, the gaze direction of distractor faces does not impact on the gaze direction judgement of target faces, suggesting that eye gaze direction is only perceived when within the focus of attention (Burton, Bindemann, Langton, Schweinberger, & Jenkins, 2009). Further, covert looking at the eyes is not sufficient to elicit the typical facial encoding advantage seen when the eyes are directly engaged (Laidlaw & Kingstone, 2017).

Senju and Johnson (2009) have proposed a 'fast track modulator' model to account for the effect of eye contact on social cognitive processing and social behaviour (see also Johnson, Senju, & Tomalski, 2015). They argue that a subcortical face detection pathway, including the superior colliculus, pulvinar and amygdala, is responsible for rapidly detecting eye contact. This pathway, in combination with contextual modulation driven by task demands and social context, modulates activity in the cortical social brain network. It has previously been suggested that the superior colliculus is involved in reflexive, stimulus driven eye gaze, compared to cortically modulated eye gaze that is goal directed and under voluntary control (see Theeuwes, Kramer, Hahn, & Irwin, 1998). Importantly, this reflexive gaze cannot always be effectively inhibited by intention to look elsewhere (Theeuwes et al., 1998). Study of patient SM, who has complete bilateral lesions of the amygdala, has demonstrated that the amygdala is instrumental for fixations to the eyes. Her reduced looking to the eyes was strongest during first fixations, where she only looked at the eyes on 15% of trials, compared to 74% in control participants (Kennedy & Adolphs, 2011). Notably, when the face was hidden and areas only revealed when fixated, thus removing bottom-up competition between facial features and supporting deliberate looking, SM's patterns of abnormal gaze were normalised. These findings support the role of the amygdala in guiding fixations, particularly first fixations, to socially salient parts of the face. Converging theory and research therefore supports the argument that the amygdala and superior colliculus support reflexive, bottom-up eye gaze, compatible with a role in the difficult to inhibit first look to the eyes observed in the current study.

An alternative explanation for the hard-to-supress first look to the eyes is that they are an optimal location for face processing i.e. a central location that maximises encoding of diagnostic information (van Belle et al., 2010). The 'centre of gravity' effect (e.g. Coren & Hoenig, 1972; Findlay, 1982; Findlay & Gilchrist, 1997), which is the tendency to look first to the centre of an image, has been observed for face perception where the location on screen and/or the orientation of the faces varied (Bindemann et al., 2009; Hills, Sullivan, & Pake, 2012; Hsiao & Cottrell, 2008). However, bias to the geometric centre was not observed when, as in the current study, the location of the face was predictable, either with (Brielmann et al., 2014) or without (Peterson & Eckstein, 2012, 2013) the orientation of the face changing. Further research would benefit from exploring first looks to the eyes, and the capacity for inhibiting this first look, in contexts that present faces with both predictable and unpredictable orientation and location of faces. Related to this, fixation patterns for dynamic stimuli or stimuli with a higher contextual load (e.g. social scenes), which are both less predictable and more complex, would be important to investigate. There is already good evidence that the eyes attract attention in scenes and videos, and cognitive control in such situations might be challenging (Birmingham et al., 2009; Foulsham & Sanderson, 2013).

There are further contextual factors that need to be investigated to better understand the scope and extent of the difficulty in inhibiting first looks to the eyes. For example, the current study used direct eye gaze, which has special status compared to averted eye gaze, activating regions of the social brain and having a key role in indicating communicative intent (e.g. Caruana et al., 2015; Cavallo et al., 2015; Conty et al., 2007; Ethofer et al., 2011; Kampe et al., 2003). Further, eye movements are preferentially drawn towards faces with direct, rather than averted gaze, even when the images are outside of conscious awareness (Rothkirch, Madipakkam, Rehn, & Sterzer, 2015). Therefore, whether such strong effects would be achieved for faces with averted eyes is important to establish. It is also relevant to consider the motivation behind the looking; our participants oriented to the faces in order to process identity. However, looking to the face often occurs when identity is known and is motivated by other factors, such as social signalling. It is intuitive to assume that the bias to initially orient to the eyes would be present when making a social overture, as direct gaze is an effective non-verbal signal of social intent (Kampe et al., 2003). Additionally, although other regions of the face can be more diagnostic than the eyes when emotional expression is being read (e.g. Gosselin & Schyns, 2001; Schurgin et al., 2014), first looks to the eye region are observed across identity, expression and gender discrimination (Peterson & Eckstein, 2012; Scheller et al., 2012). Therefore, further exploration of the limits of the bias to look to the eyes would be fruitful, specifically whether difficulty inhibiting first looks is robust in situations where faces are being 'read' for information other than identity.

Another relevant contextual consideration is the task instructions, following our instructions benefited task performance but the positive benefits could have been greater (e.g. financial reward) and negative consequences could be stronger than merely a potential decrement in task performance. A further test of eye bias would be to investigate whether it can be moderated by the prospect of positive reward or negative consequences. A final important contextual issue is that we used child faces. We have no empirical or theoretical reason to predict that the bias to look to the eyes would be different for adult faces. Although infant faces are known to capture adults' attention more readily than adult faces, this is not the case for child faces unless they express distress (Thompson-Booth et al., 2014). However, we are not aware of any study that has compared patterns of eye gaze in adults for child and adult faces. The well characterised own-age bias in face recognition (Rhodes & Anastasi, 2012) suggests replication in stimuli of different ages would be informative.

Further research should also explore individual differences in first look fixations, which are an important consideration in eye gaze research (Kanan, Bseiso, Ray, Hsiao, & Cottrell, 2015; Mehoudar, Arizpe, Baker, & Yovel, 2014; Peterson & Eckstein, 2013). For example, those who show a stronger first look bias to the eyes, or who regulate (e.g. disengage) their first looks more proficiently, may be evaluated more positively by others. Further, the strength of the bias to look to the eyes, particularly whether it is amenable to suppression, has potential to discriminate between populations. Individuals with insomnia (Akram, Ellis, Myachykov, & Barclay, 2017) and high levels of neuroticism (Perlman et al., 2009) are known to give greater attention to the eye region. In contrast, avoidance of the eye region (Horley, Williams, Gonsalvez, & Gordon, 2004) and fear of direct eye contact (Schulze, Renneberg, & Lobmaier, 2013) is characteristic of those with social anxiety. Particularly relevant to the current paradigm, the psychopathic trait of boldness was associated with delayed first looks to the eyes, alongside shorter dwell times and fewer visits to the eyes (Gillespie, Rotshtein, Beech, & Mitchell, 2017). Atypical eye gaze is also observed in individuals with autism spectrum disorder (ASD) and Williams syndrome, with autistic individuals often spending less time looking at faces and those with Williams syndrome showing excessive looking towards the eyes (e.g. Riby & Hancock, 2008; Riby & Hancock, 2009). Whether these populations show a difficulty in inhibiting first look to the eyes, which can be considered a hallmark of typical looking, remains to be established.

It is also important to recognise that differences have been found between cultures in the pattern of looking to the face (Blais, Jack, Scheepers, Fiset, & Caldara, 2008). Most studies have not focussed on first fixations but we are aware of two studies that find contrasting results, evidencing both similarity (Or, Peterson, & Eckstein, 2015) and difference (Hills et al., 2013) between cultural groups. Our participants were predominantly from the United Kingdom and the generalisability of our eye bias effect across cultures would be another important avenue for future research.

4.1. Conclusions

Catching the gaze of a stranger across a crowded room can be a disconcerting event. The current study suggests that it is our natural bias to orient to the eyes that causes this social phenomenon and that our conscious intent not to look at the eyes may prove futile. Even when explicitly told that looking at the mouth would benefit task performance, our participants were unable to fully inhibit looking to the eyes, which is compatible with the eyes automatically drawing attention. Although our study focussed on the location of first looks, the duration of first looks could be equally informative. For example, looking into someone's eyes for too long can be an uncomfortable experience and one or both parties usually disengages from sustained eye contact after a relatively short period of time. Understanding the offset of the first look eye fixation is important in fully characterising the eye bias. Further work should also explore how robust the eye bias is across different contexts, as well as investigate individual differences in the general population and the presence or absence of the phenomenon in atypical populations.

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Declaration of interests

None.

Appendix A. Normalised data

A.1. Normalisation method

We adopted the same normalisation procedure as Laidlaw et al. (2012), among others (e.g. Bindemann et al., 2009; Birmingham et al., 2008; Fletcher-Watson et al., 2008). To normalise, for each trial, the total dwell time per ROI or the total number of first fixations to that ROI were converted to percentages based on the total amount of time or fixations, and this figure was divided by the percentage pixel area of the screen taken up by that ROI (e.g. percentage eye dwell time/ percentage of the screen taken up by the eye ROI). These calculations create a ratio value, whereby a value of one indicates that a region was looked at as much as would be expected if looking across the whole screen was random. A value above one indicates that a participant looked to that ROI more than would be predicted if looking were random, and a value less than one indicates participants looked to the area less than would be predicted if looking were random. Thus, values above one indicate a looking bias to the ROI. In addition, a value of zero indicates that the ROI was not fixated at all.

A.2. Summary of key findings

	Key finding	Statistics
Unprompted looking patterns	First fixations were significantly more often to the eyes (mean = 13.83, sd = 6.22) than to the mouth (mean = 0.85, sd = 2.11)	t(40) = 11.45, $p < 0.001$, d_{av} = 3.11, 90% CI [2.66, 3.58]
	Dwell time was significantly longer for the eyes (mean = 20.88, sd = 6.81) than for the mouth (mean = 1.56, sd = 2.70)	t(40) = 14.68, $p < 0.001$, d_{av} = 4.06, 90% CI [3.30, 4.16]
Prompted looking patterns	When participants were prompted to look to the eyes their first fixation on the target image was significantly more often to the eyes (mean = 13.35, sd = 6.94) than the mouth (mean = 1.76, sd = 4.92)	t(40) = 7.70, $p < 0.001$, d_{av} = 1.95, 90% CI [1.51, 2.35]
	When prompted to look to the mouth there was no significant difference between first fixations to the eyes (mean = 11.71, sd = 5.12) and the mouth (mean = 10.34, sd = 10.04)	t(40) = 0.68, p = 0.50, d_{av} = 0.18, 90% CI [−0.26, 0.62]
	When prompted to look at the eyes participants spent longer looking to the eyes (mean = 22.11, sd = 5.19) than to the mouth (meam = 2.81, sd = 5.03)	t(40) = 14.06, $p < 0.001$, d_{av} = 3.78, 90% CI [3.32, 4.23]
	When prompted to look at the mouth participants spent longer looking to the mouth (mean = 28.83, sd = 16.24) than to the eyes (mean = 6.12, sd = 3.52)	t(40) = 8.12, $p < 0.001$, d_{av} = 2.30, 90% CI [1.53, 2.33]

A.3. Full normalised results

A.3.1. Unprompted looking patterns

A t-test showed that participants' first fixations were significantly more often to the eyes (mean = 13.83%, sd = 6.22), than the mouth (mean = 0.85%, sd = 2.11), t(40) = 11.45, $p < 0.001$, d_{av} = 3.11, 90% CI [2.66, 3.58]. It is also notable that first looks to the eyes occur far more often (i.e. normalised value > 1) than would be expected for their size, whereas first looks to the mouth occur less (i.e. < 1) than would be expected for its size. In addition, total dwell time was significantly longer for the eyes (mean = 20.88 ms, sd = 6.81), than the mouth (mean = 1.56 ms, sd = 2.70), t(40) = 14.68, $p < 0.001$, d_{av} = 4.06, 90% CI [3.30, 4.16].

A.3.2. Prompted looking patterns

For the first look data we found a significant main effect of prompt location, F(1,40) = 17.53, $p < 0.001$, η_p^2 = 0.31, 90% CI [0.12, 0.46], a significant effect of ROI, F(1,40) = 21.95, $p < 0.001$, η_p^2 = 0.35, 90% CI [0.15, 0.50], and a significant interaction, F(1,40) = 21.53, $p < 0.001$, η_p^2 = 0.35, 90% CI [0.15, 0.50]. Post hoc t-tests (Bonferroni threshold of $p < 0.025$) revealed that when participants were prompted to look to the eyes their first fixation on the target image was significantly more often to the eyes (mean = 13.35%, sd = 6.94) than the mouth (mean = 1.76%, sd = 4.92), t(40) = 7.70, $p < 0.001$, d_{av} = 1.95, 90% CI [1.51, 2.35]. However, when prompted to look to the mouth there was no difference between first fixations to the eyes (mean = 11.71%, sd = 5.12) and the mouth (mean = 10.34%, sd = 10.04), t(40) = 0.68, p = 0.50, d_{av} = 0.18, 90% CI [−0.26, 0.62]. See Fig. A1.

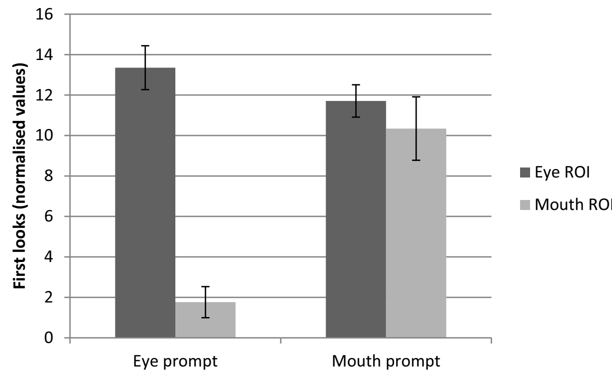

Fig. A1. Area normalised first looks to the eye and mouth regions of interest (ROI) when prompted to look to the eyes or mouth (error bars show standard error).

For the dwell time data we found a significant main effect of prompt location, $F(1,40) = 19.52$, $p < 0.001$, $\eta_p^2 = 0.32$, 90% CI [0.14, 0.48], no significant effect of ROI, $F(1,40) = 1.22$, $p = 0.28$, $\eta_p^2 = 0.03$, 90% CI [0.00, 0.15], and a significant interaction, $F(1,40) = 179.70$, $p < 0.001$, $\eta_p^2 = 0.82$, 90% CI [0.72, 0.86]. This significant interaction is the result of participants looking significantly more often to the eyes than to the mouth when prompted to look at the eyes, $t(40) = 14.06$, $p < 0.001$, $d_{av} = 3.78$, 90% CI [3.32, 4.23], and significantly more often to the mouth than the eyes when prompted to look to the mouth, $t(40) = 8.12$, $p < 0.001$, $d_{av} = 2.30$, 90% CI [1.53, 2.33]. See Fig. A2.

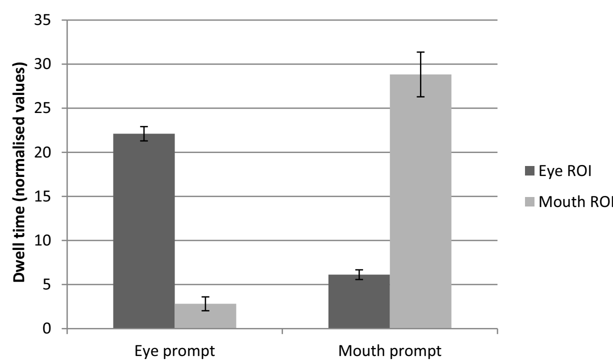

Fig. A2. Area normalised mean dwell time for the eye and mouth regions of interest (ROI) when prompted to look to the eyes or mouth (error bars show standard error).

A.4. Comparison of eye looking in unprompted and eye prompted conditions

Using *t*-tests, we found there were no differences between these two conditions, for both first fixations and dwell time (all $ps < 0.05$), suggesting eye looking is already at maximum capacity in the unprompted condition.

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